

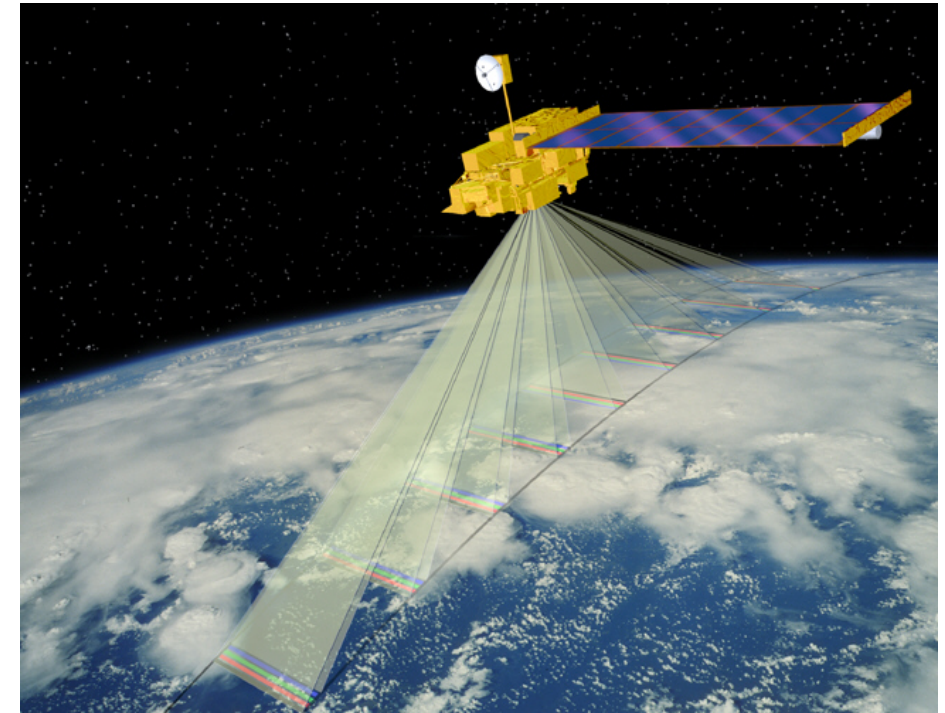
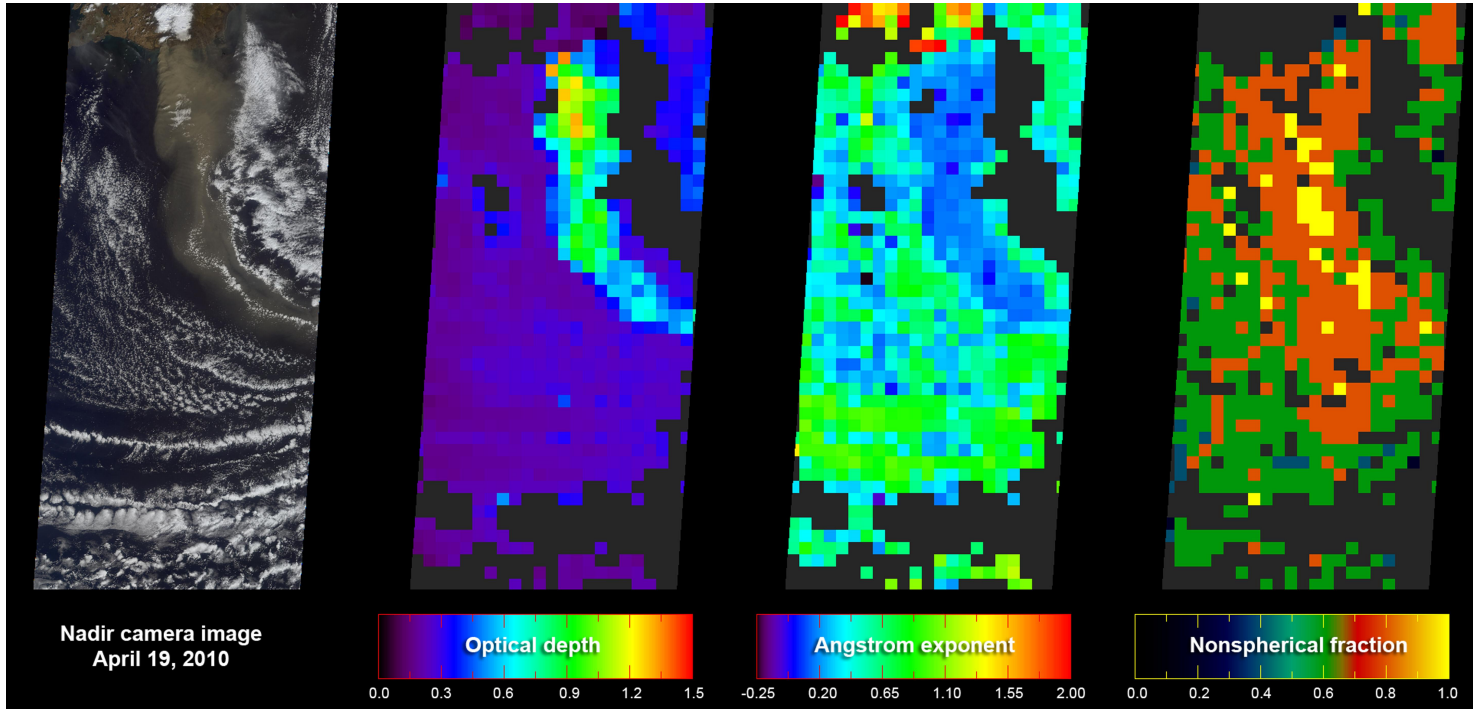
Multi-resolution investigation of smoke observations: the value added by datasets at high spatial resolutions

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Aerosol observations from the Multi-angle Imaging SpectroRadiometer (MISR)

MISR views of Eyjafjallajökull – 4/19/2010

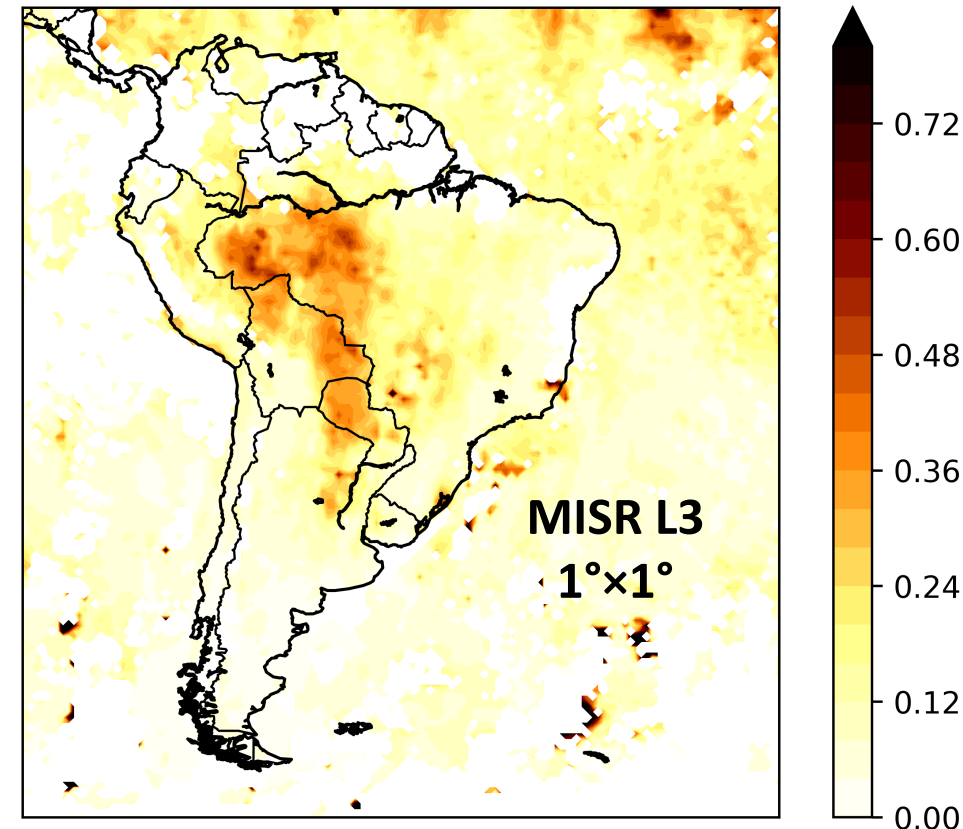
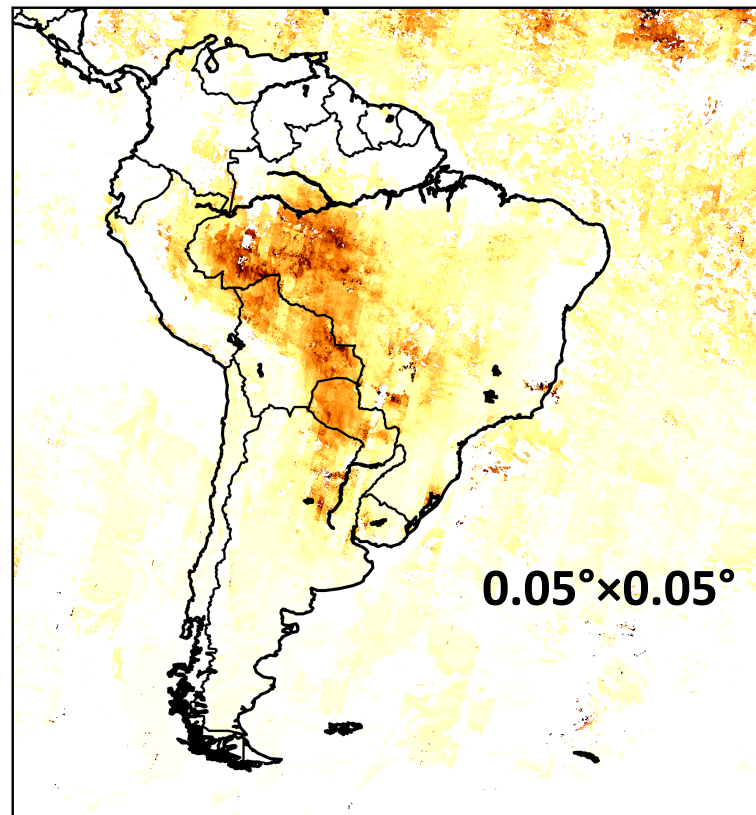
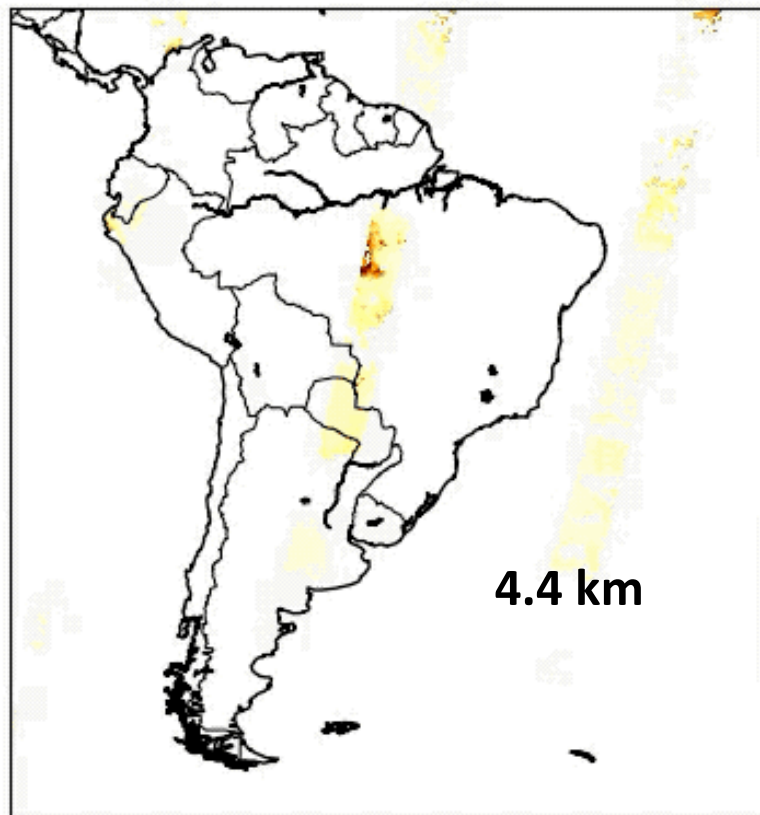


- The latest MISR aerosol optical depth (AOD) product (V23, Garay et al., 2020) has the horizontal resolution of 4.4 km, which is higher than 17.6 km resolution in V22.
- What is the value added by AOD datasets at higher spatial resolution?

Motivation

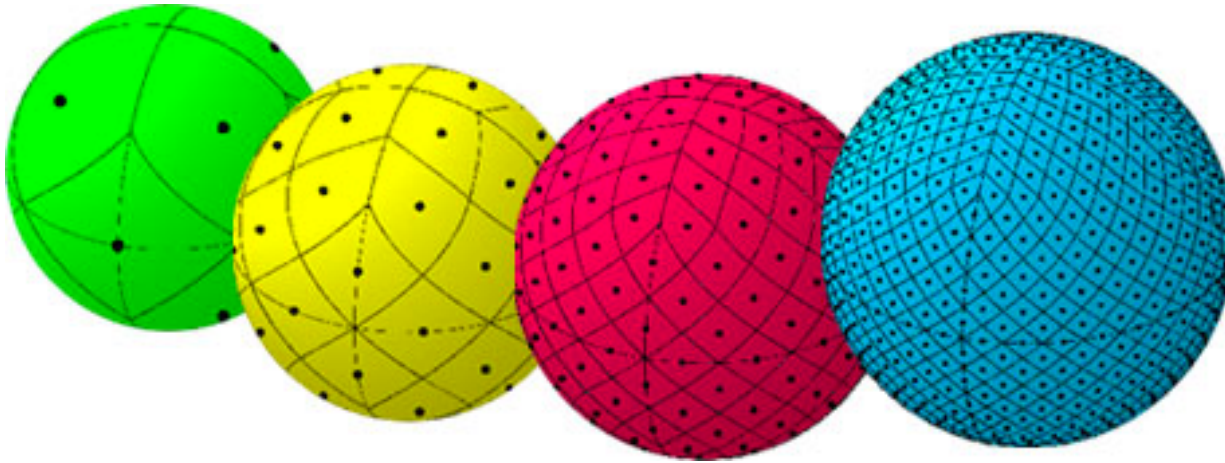
- How can we quantify the added value of high-resolution (4.4 km) AOD datasets?

MISR AOD in August 2019



Hierarchical Equal Area isoLatitude Pixelization (HEALPix, <https://healpix.jpl.nasa.gov>)

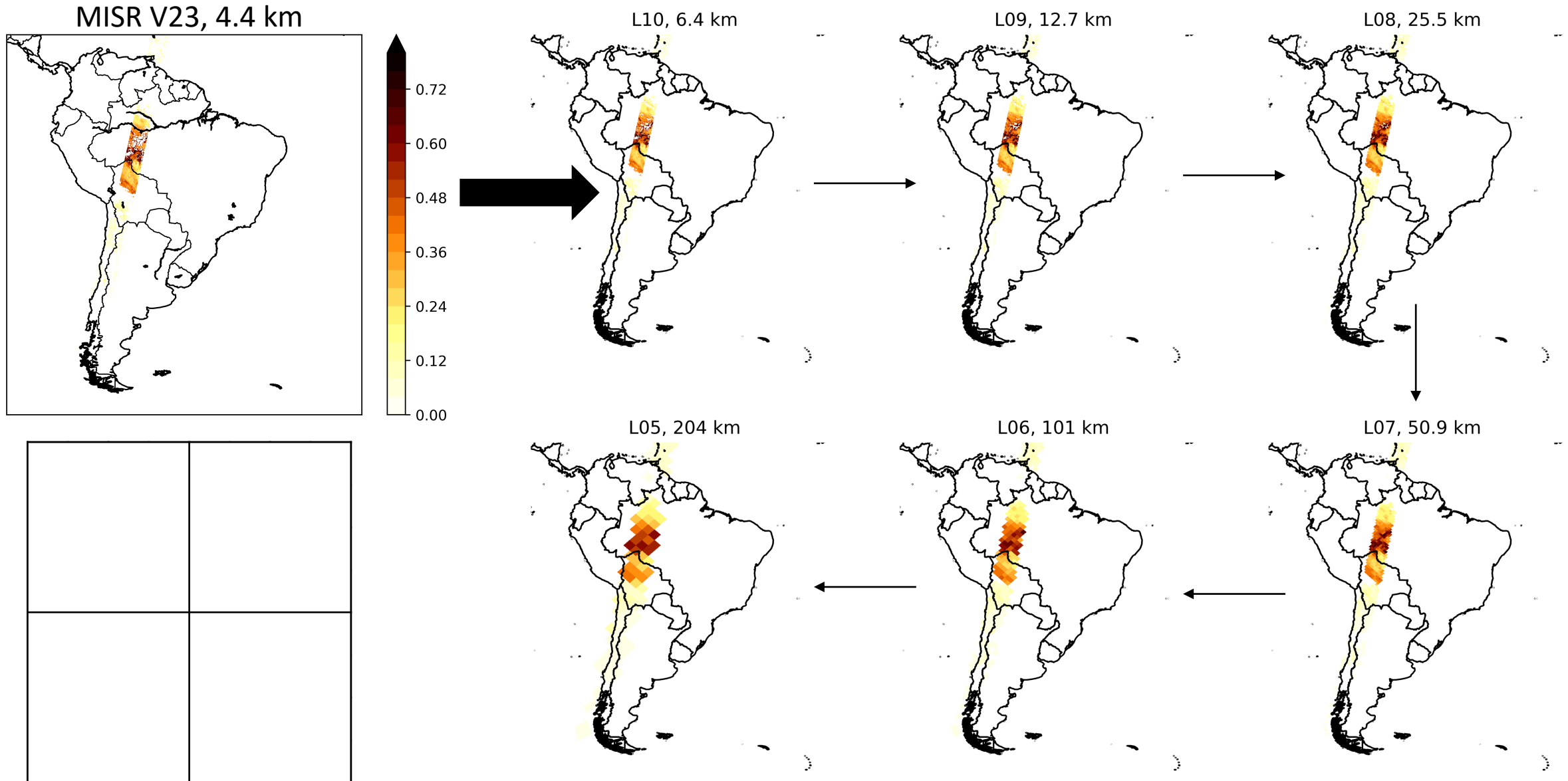
HEALPix levels (0, 1, 2, 3) and corresponding grids



HEALPix level	Resolution [km]	# of grid points
5	203.74	12,288
6	101.87	49,152
7	50.93	196,608
8	25.47	786,432
9	12.73	3,145,728
10	6.37	12,582,912
11	3.18	50,331,648
12	1.59	201,326,592
13	0.80	805,306,368

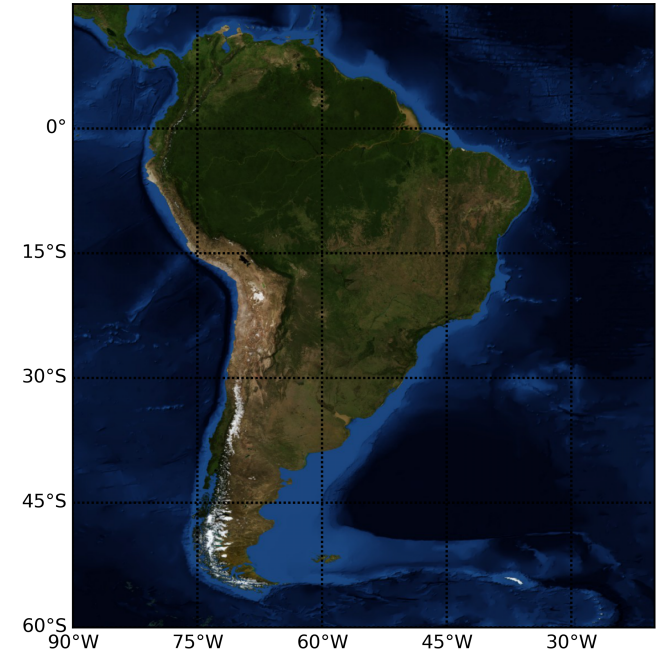
- All HEALPix grid pixels have exact equal areas regardless of their geographical locations and resolutions.
- Geographical coordinates of HEALPix pixels are fixed, and higher resolution pixels are hierarchically nested within lower resolution pixels.
- Generating low-resolution data from high-resolution data on HEALPix grids is a simple and efficient averaging process that utilizes their hierarchical data structure.

Remapping MISR L2 AOD into HEALPix grids

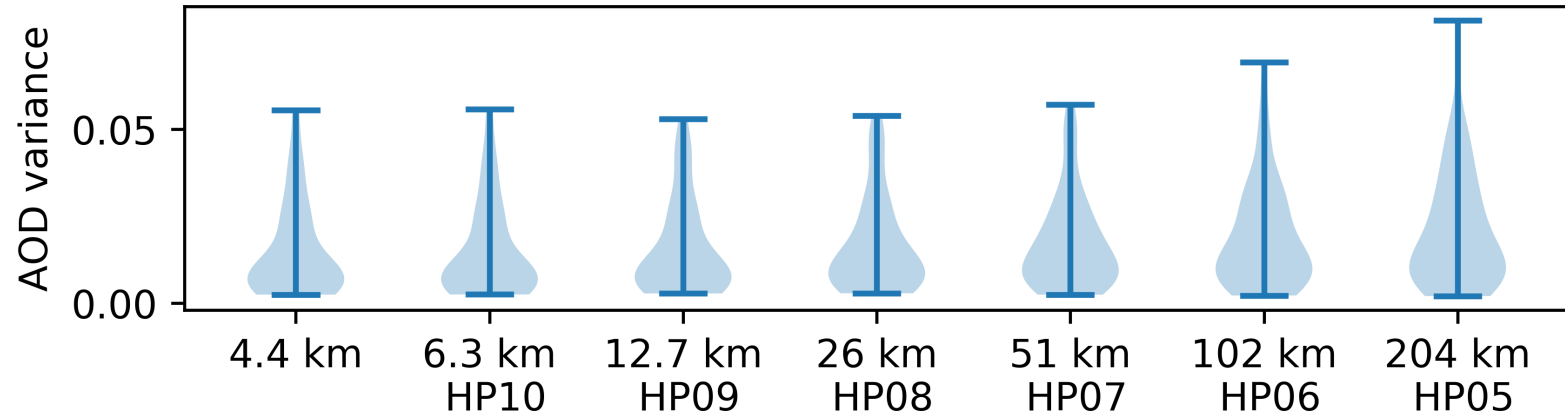


Multi-resolution investigation

- Analyses of spatial features at coarse (e.g. 100 km) and fine scales (spatial scales of around 10 km or smaller) separately.
 - spatial variance of AOD at different resolutions
 - difference between two AOD maps at different resolutions
 - anisotropic spatial patterns in AOD maps
- L2 AOD retrieved along 64 satellite paths in August 2019.

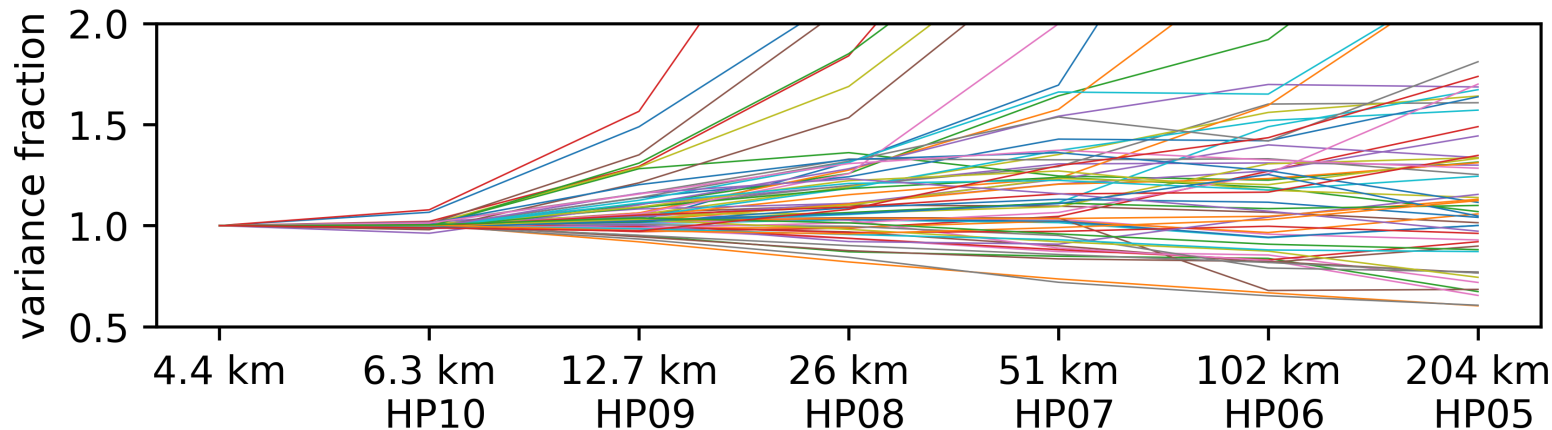


Spatial variance of AOD at different scales



- Remapping MISR V23 AOD at 4.4 km resolution into HEALPix grids (6.3 km, L10) does not significantly change spatial variability.

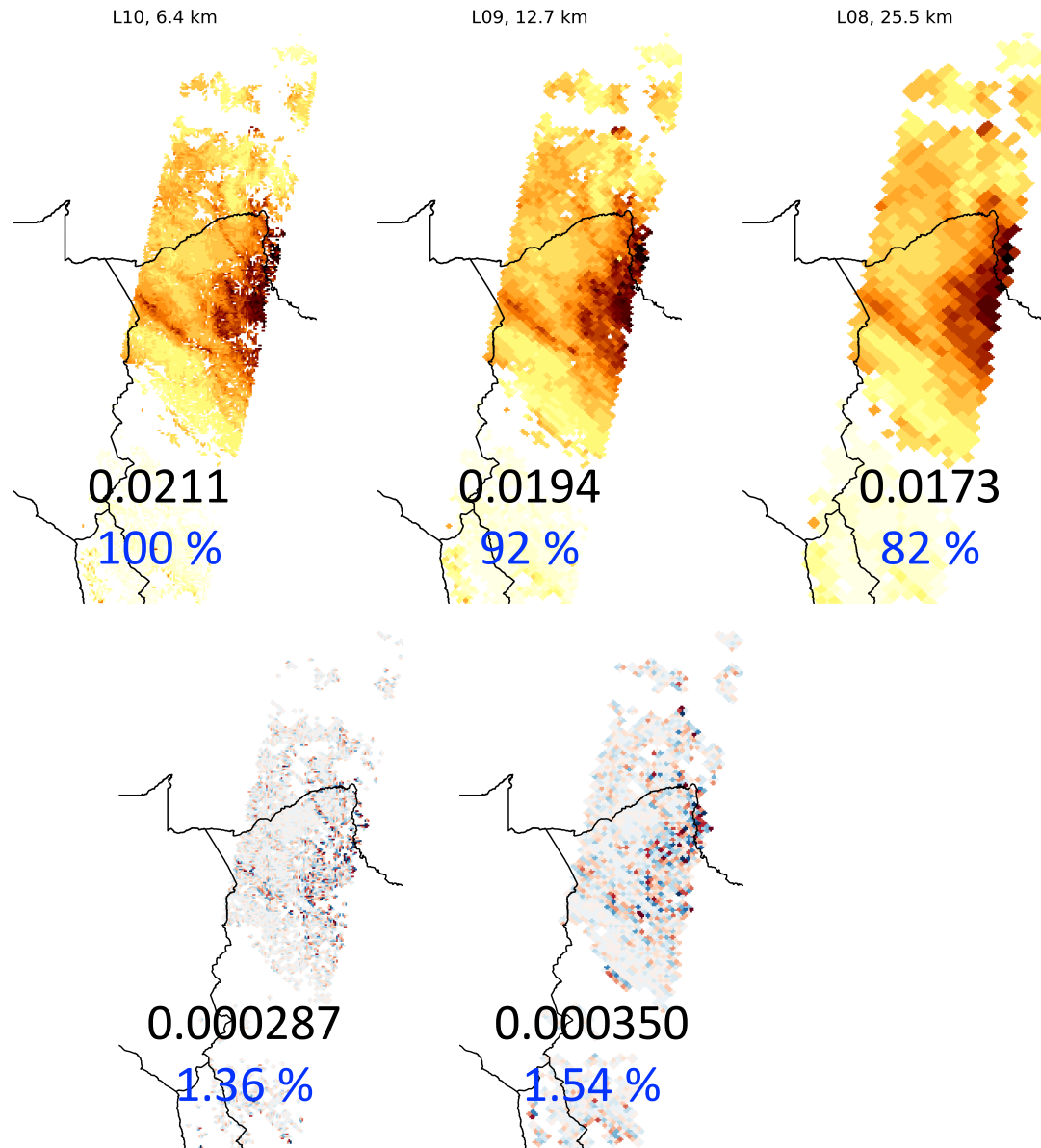
$$fraction = \frac{variance_x}{variance_{4.4km}} \text{ where } x=6.3, 12.7, 26, 51, 102, \text{ or } 204 \text{ km}$$



- By spatially averaging high resolution AOD data into low resolution grid points:
 - fine-scale spatial information is lost, or
 - variability increases due to anomalous high AOD values.

variability at high resolution

→ variability at low resolution + residual variability



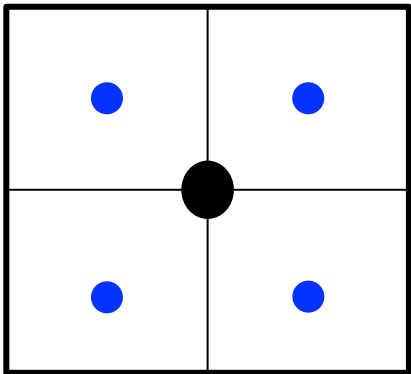
$$\begin{bmatrix} 0.2 & 0.3 \\ 0.6 & 0.5 \end{bmatrix} = \begin{bmatrix} 0.2 & 0.3 \\ 0.6 & 0.5 \end{bmatrix} - \begin{bmatrix} 0.4 & 0.4 \\ 0.4 & 0.4 \end{bmatrix} = \begin{bmatrix} -0.2 & -0.1 \\ 0.2 & 0.1 \end{bmatrix}$$

- Thanks to the unique hierarchical structure, it is possible to calculate and visualize differences between two datasets remapped at different HEALPix resolutions.
- The added value of high-resolution AOD data is equivalent to the fine-scale features to be lost when spatially averaging high-resolution data.

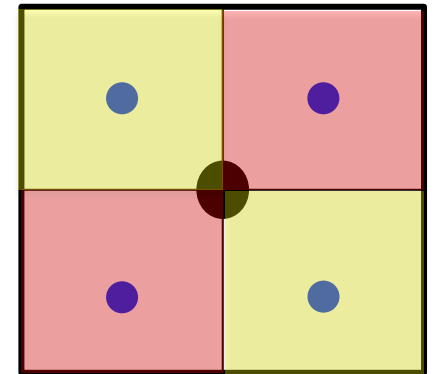
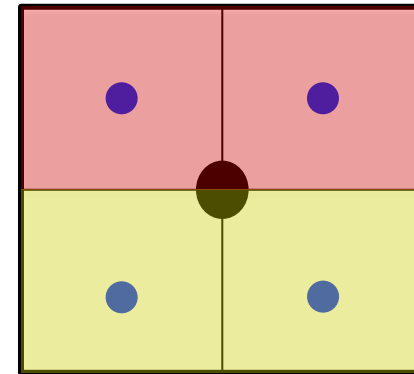
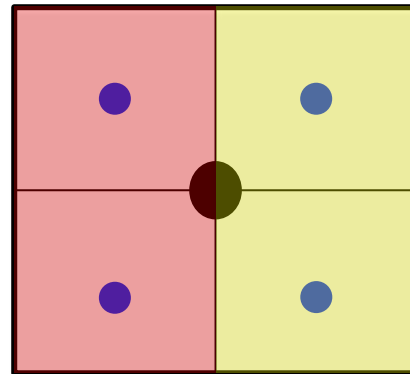
Gorski wavelet

- Unlike the Harr wavelet, the numbers of x and y grids do not have to be 2^n .
- Spatial gradients are not limited to x- and y-gradients.
- We can check the isotropic assumption of a spatial stochastic process:
 - spatial dependence between two locations can be represented as a function of the distance only.

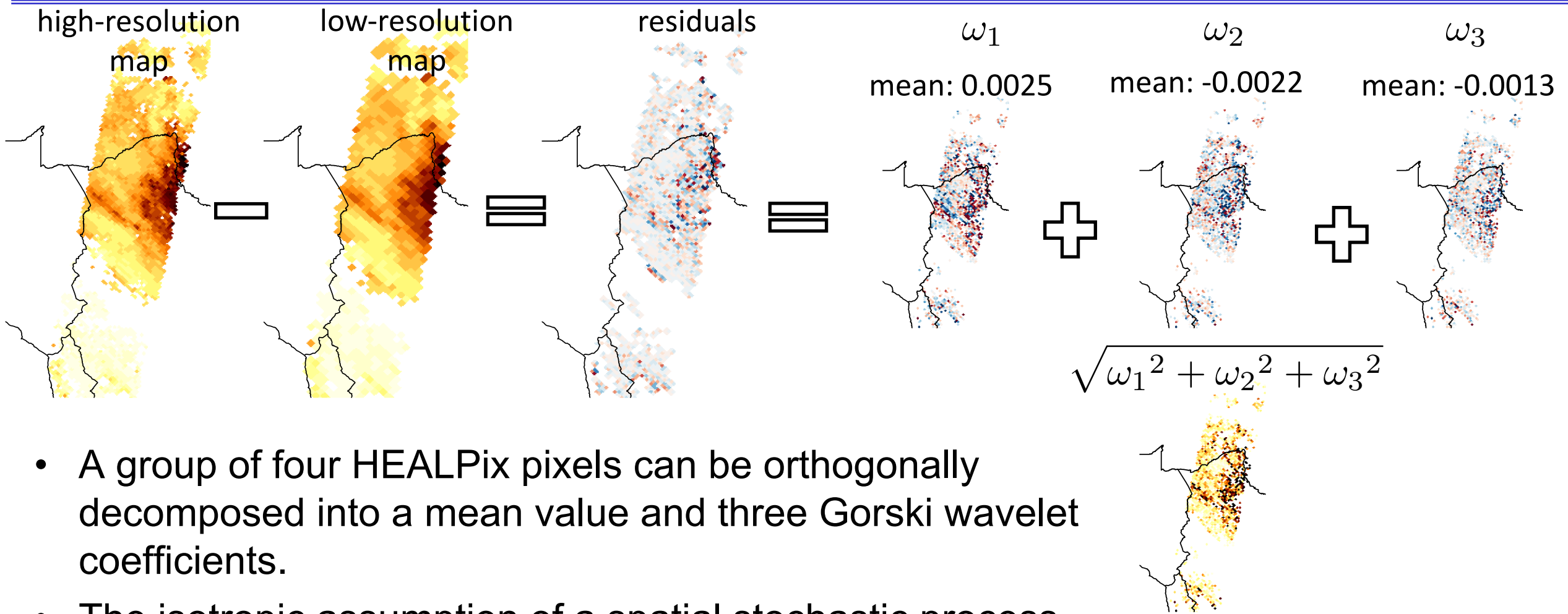
Decomposition of four high-resolution values (●)



Spatial basis functions

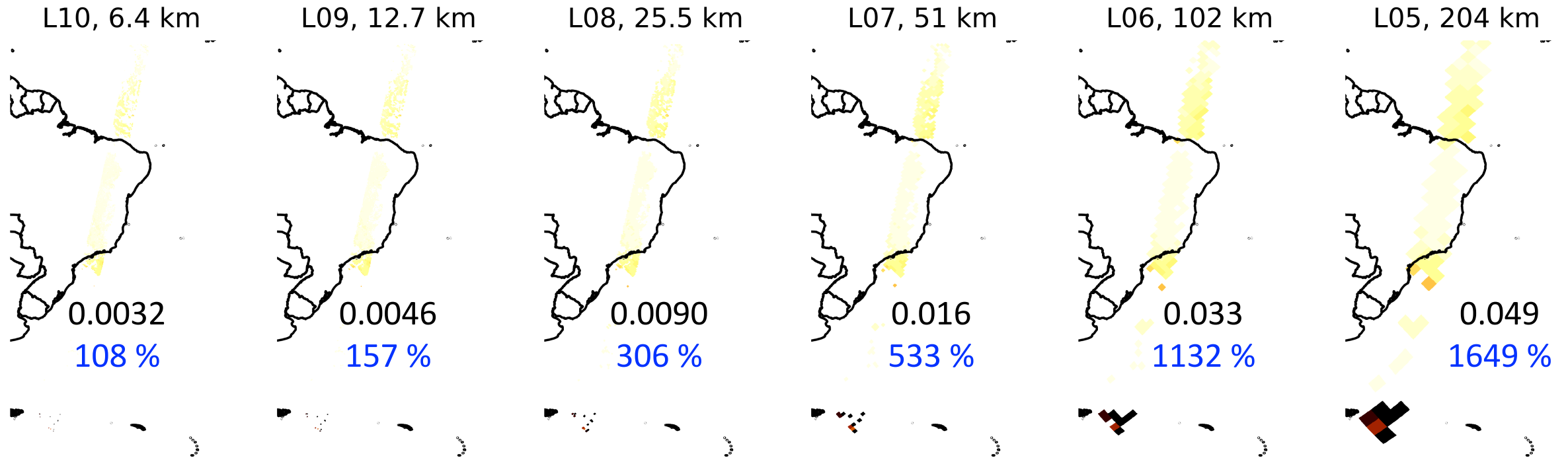


Spatial decomposition of AOD maps



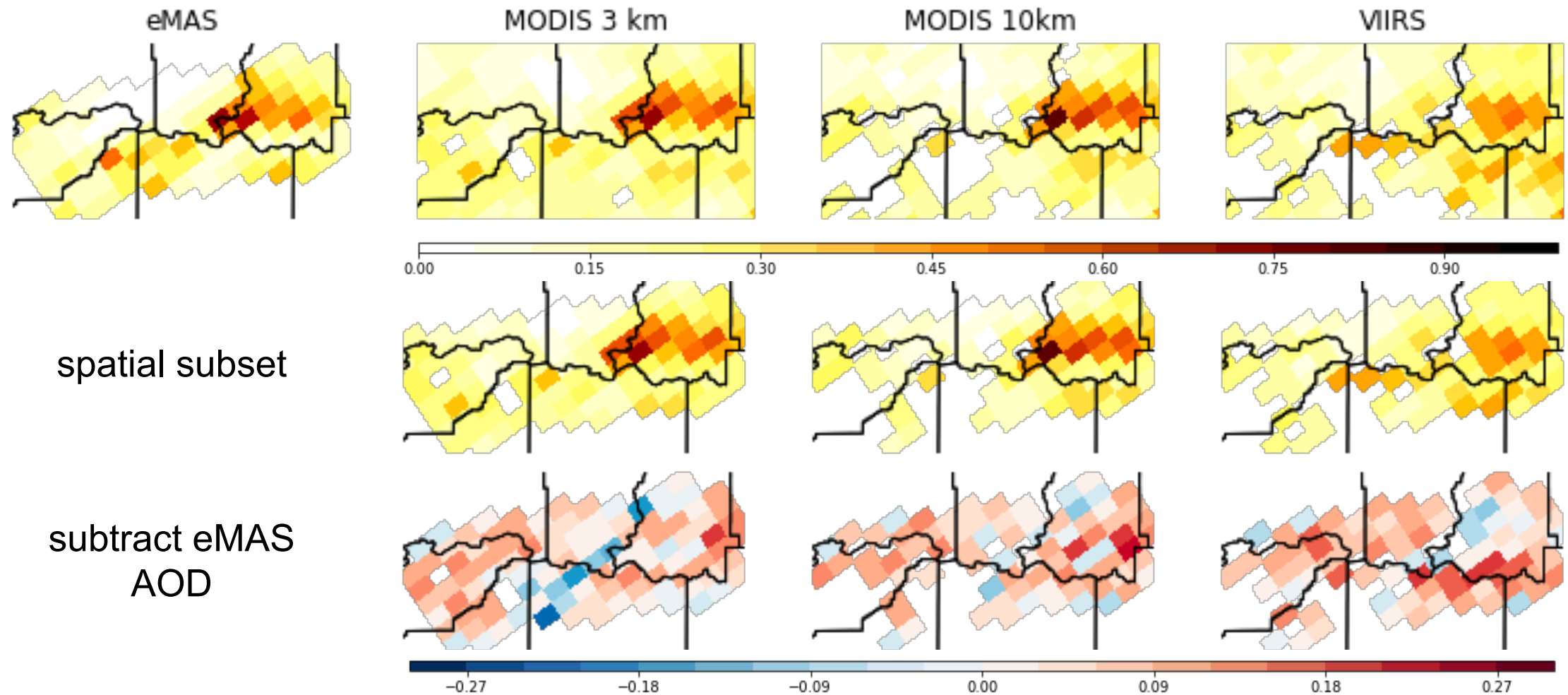
- A group of four HEALPix pixels can be orthogonally decomposed into a mean value and three Gorski wavelet coefficients.
- The isotropic assumption of a spatial stochastic process may not be valid in this case:
 - a variogram should account for anisotropy.

Amplification of anomalous retrievals at lower spatial resolution



- (Generally) the higher spatial resolution, the greater spatial variance of observations.
- Conventional upscaling (aggregation of retrieved values and averaging them) to remap AOD at higher resolution into lower resolution grids can amplify anomalously high AOD retrievals.

AOD Differences among eMAS, MODIS, and VIIRS during the Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ) campaign



Bias	0.036	0.053	0.062
RMSE	0.080	0.086	0.092

Conclusions

- HEALPix offers capabilities that can decompose spatial variability in AOD at high resolution (4.4 km) and show the added value of MISR V23 AOD.
- The key question always raised while designing new observation strategy: how high should be the spatial resolution of the new data products from future missions?
 - Our case study indicates that it is important to provide observations of AOD from wildfires at 4.4 km over South America. At coarser resolutions than 10 km, AOD maps over the region do not represent the fine-scale variability in AOD.
 - Aggregation of MISR V23 AOD into low resolution grids (e.g., MISR L3 AOD's resolution of 1°) can amplify anomalously high AOD values.
 - The residual patterns cannot be assumed as random white noise.